MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2022/2023 (TERM ID 2210)

ETN3136 – DIGITAL COMMUNICATIONS

(TE)

7 FEBRUARY 2023
9:00 A.M – 11:00 A.M
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of 5 pages including cover page with **4** Questions only.
2. Attempt **ALL FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given.
3. Please write all your answers in the Answer Booklet provided.

Question 1

(a) Figure Q1(a) shows the amplitude response and phase response of a channel. Deduce the type of distortion that is experienced by the following signals after passing through this channel.

(i) $x(t) = \cos 40\pi t + \cos 120\pi t$

[4 marks]

(ii) $y(t) = \cos 140\pi t + \cos 190\pi t$

[4 marks]

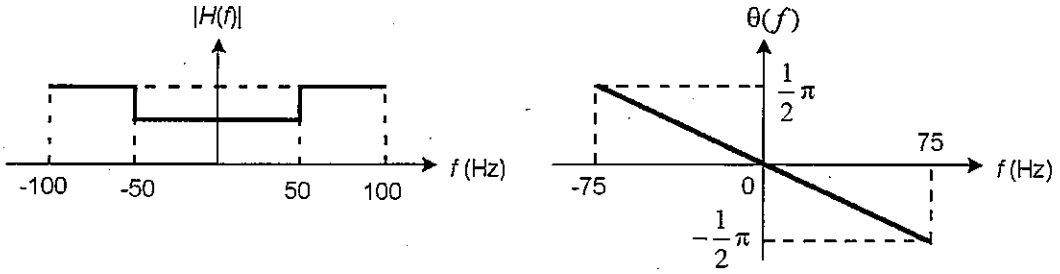

Figure Q1(a)

(b) Explain how a non-uniform quantizer uses varying step-size Δ to stabilize the output signal-to-quantization noise ratio irrespective of the input signal's amplitude.

[6 marks]

(c) In a pulse code modulation (PCM) system, a uniform quantizer with 512 quantization levels is used. An analog signal with a bandwidth of 40 kHz is to be digitized. It is first sampled at 50% above the Nyquist frequency.

(i) Calculate the sampling rate and the number of binary bits required to encode each of these samples.

[2 marks]

(ii) Calculate the bit rate of the PCM signal and the minimum bandwidth that this signal requires.

[2 marks]

(iii) Determine the number of quantization levels of the quantizer if the maximum acceptable quantization error is 1% of the analog signal's peak amplitude (note that the number of quantization levels must be the nearest power of 2 to the calculated value).

[5 marks]

(iv) Calculate the new bit rate of the PCM signal and the corresponding minimum bandwidth it requires after taking into account the condition in (c)(iii).

[2 marks]

Continue...

Question 2

(a) A binary data sequence of 1110010100 is first differentially encoded (assume bit 0 for the reference bit) and then line coded for transmission over a baseband channel.

(i) Write down the differentially encoded binary data sequence.

[3 marks]

(ii) Sketch the transmitted signal waveform when using unipolar non-return-to-zero line code.

[3 marks]

(iii) Sketch the transmitted signal waveform when using polar non-return-to-zero line code.

[3 marks]

(b) The power spectral density of a unipolar return-to-zero (RZ) is shown in Figure Q2(b). The transmission rate is denoted as R in the figure. With a suitable circuit diagram, briefly explain the procedure to recover the clock signal for bit synchronization from the unipolar RZ waveform.

[8 marks]

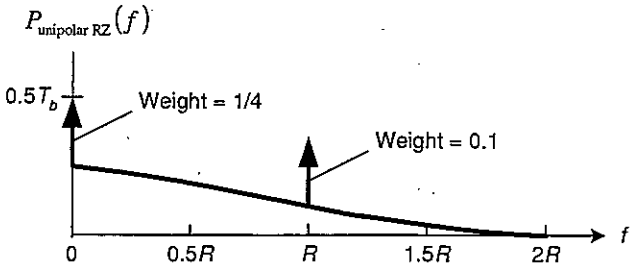

Figure Q2(b)

(c) In a particular communication system, information is transmitted at a data rate of 30 Mbits/s over the air using quadrature phase-shift keying (QPSK) modulation while occupying a bandwidth of 24 MHz.

(i) If the raised cosine filter is used for pulse shaping, calculate the roll-off factor, r.

[2 marks]

(ii) Is the communication system still feasible if the data rate is to be increased to 50 Mbits/s? Explain your answer.

[3 marks]

(iii) The modulation scheme is now replaced with 16-PSK. From the roll-off factor obtained in part (c)(i), calculate the bandwidth that can be saved, in Hz, if information is transmitted at a data rate of 30 Mbits/s.

[3 marks]

Continue...

Question 3

(a) The matched filter is one of the most important components of a digital receiver. When filtering the received signal, is it important for the matched filter to preserve the original signal waveform? Explain your answer.

[5 marks]

(b) A signal, $g(t)$, in the form of a rectangular pulse with amplitude, A, and duration, T, is shown in Figure Q3(b) below.

(i) Sketch the output waveform if $g(t)$ is input to a matched filter.

[3 marks]

(ii) The integrate-and-dump circuit is used to implement the matched filter. Using a suitable diagram, briefly explain the working principles of this circuit. With the signal, $g(t)$, as the input, sketch the output waveform of the integrate-and-dump circuit.

[7 marks]

(iii) By comparing your output waveforms in (b)(i) and (b)(ii), justify whether the integrate-and-dump circuit is able to implement the matched filter without loss of optimality.

[3 marks]

(c) Figure Q3(c) below shows the power spectral density, $H(f)$, of an interference signal that is affecting the performance of a digital communication system.

(i) Derive the average power, P, of the interference signal.

[4 marks]

(ii) The autocorrelation function of the interference signal is $R(\tau) = P\left(\frac{\sin \pi B\tau}{\pi B\tau}\right)^2$. Find the spacing intervals that result in the samples of the interference signal being uncorrelated.

[3 marks]

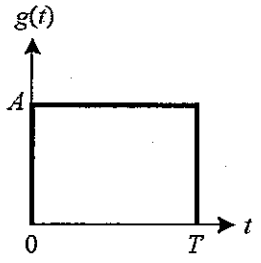

Figure Q3(b)

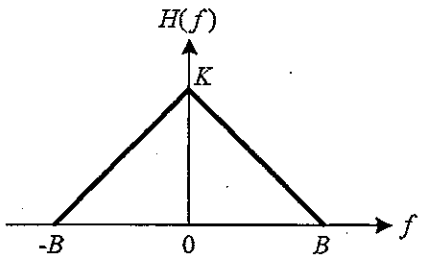

Figure Q3(c)

Continue...

Question 4

(a) The resource grid of the orthogonal frequency division multiple access (OFDMA) scheme is shown in Figure Q4(a). In this scheme, a bandwidth of 40 MHz is assigned for downlink transmission. This bandwidth is including a guard band of 4 MHz. Furthermore, it is estimated that 20% of the downlink transmission is control signaling while the remaining 80% is user data. It is decided that the control signaling utilizes BPSK modulation while the user data employs 128 QAM. Assume that the subcarrier spacing is 15 kHz and the duration of each slot, T_{slot}, is 0.5 milliseconds. Finally, the downlink transmission is carried out by using a 4x2 multiple-input multiple-output (MIMO) antenna system.

(i) Calculate the number of physical resource blocks (PRBs) that can be accommodated in the assigned bandwidth.

[2 marks]

(ii) Following that, deduce the aggregate bit rate due to both control signaling and user data for this OFDMA scheme in a single user scenario.

[11 marks]

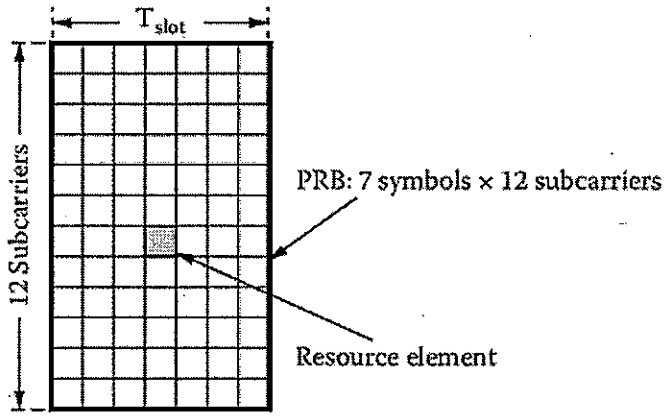

Figure Q4(a)

(b) With suitable diagrams, explain the following innovations in 5G New Radio (5G-NR).

(i) Numerology

[6 marks]

(ii) Flexible self-contained slot

[6 marks]

End of Paper